(12) UK Patent Application (19) GB (11) 2517490 (13) A

(43) Date of A Publication 25.02.2015

(21) Application No: 1315083.4

(22) Date of Filing: 23.08.2013

(71) Applicant(s):
De Montfort University
(Incorporated in the United Kingdom)
The Innovation Centre, 49 Oxford Street, LEICESTER, LE1 5XY, United Kingdom

(72) Inventor(s):
Peter Ford

(74) Agent and/or Address for Service:
Serjeants
25 The Crescent, King Street, LEICESTER, LE1 6RX, United Kingdom

(51) INT CL:
B29C 67/00 (2006.01) ***B22F 3/105*** (2006.01)

(56) Documents Cited:
None

(58) Field of Search:
INT CL **B22F, B29C**
Other: **EPODOC, WPI**

(54) Title of the Invention: **Additive manufacturing methods**
Abstract Title: **Clearing powder from passageway in additive manufactured article**

(57) An additive manufacturing method for forming a solid object 1 from powdered material is described. The solid object 1 has a passageway 4 formed therein with an opening 6a terminating at an outer surface of the solid object. The method includes the step of forming, at the same time as the remainder of the solid object 1, a removable component 8 that extends within at least part of the passageway 4. The removable component 8 is adapted so that, when it is subsequently removed from the passageway 4 by a user, it removes unprocessed powdered material 10 to at least partially clear the passageway 4. The passageway 4 may be tortuous and the removable component 8 may be articulated or flexible. A grasping feature 12a, 12b may be formed on the removable component to facilitate removal by an operator.

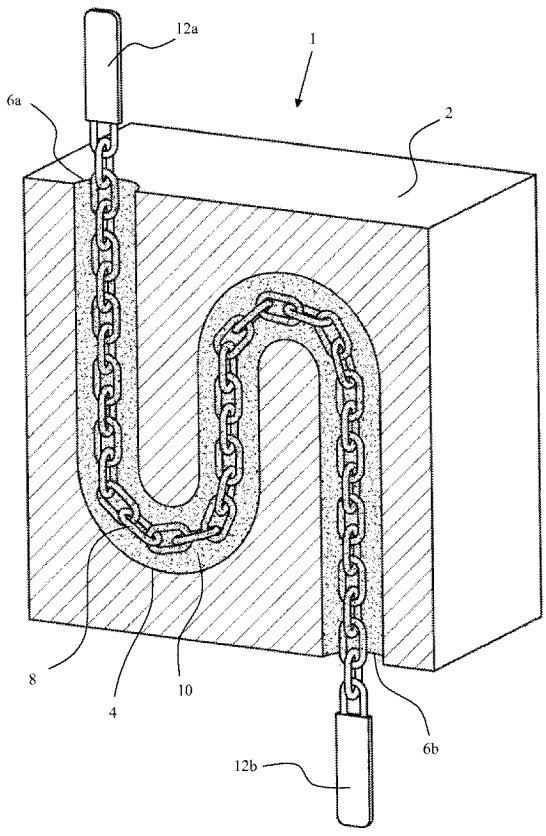

Figure 1

GB 2517490 A

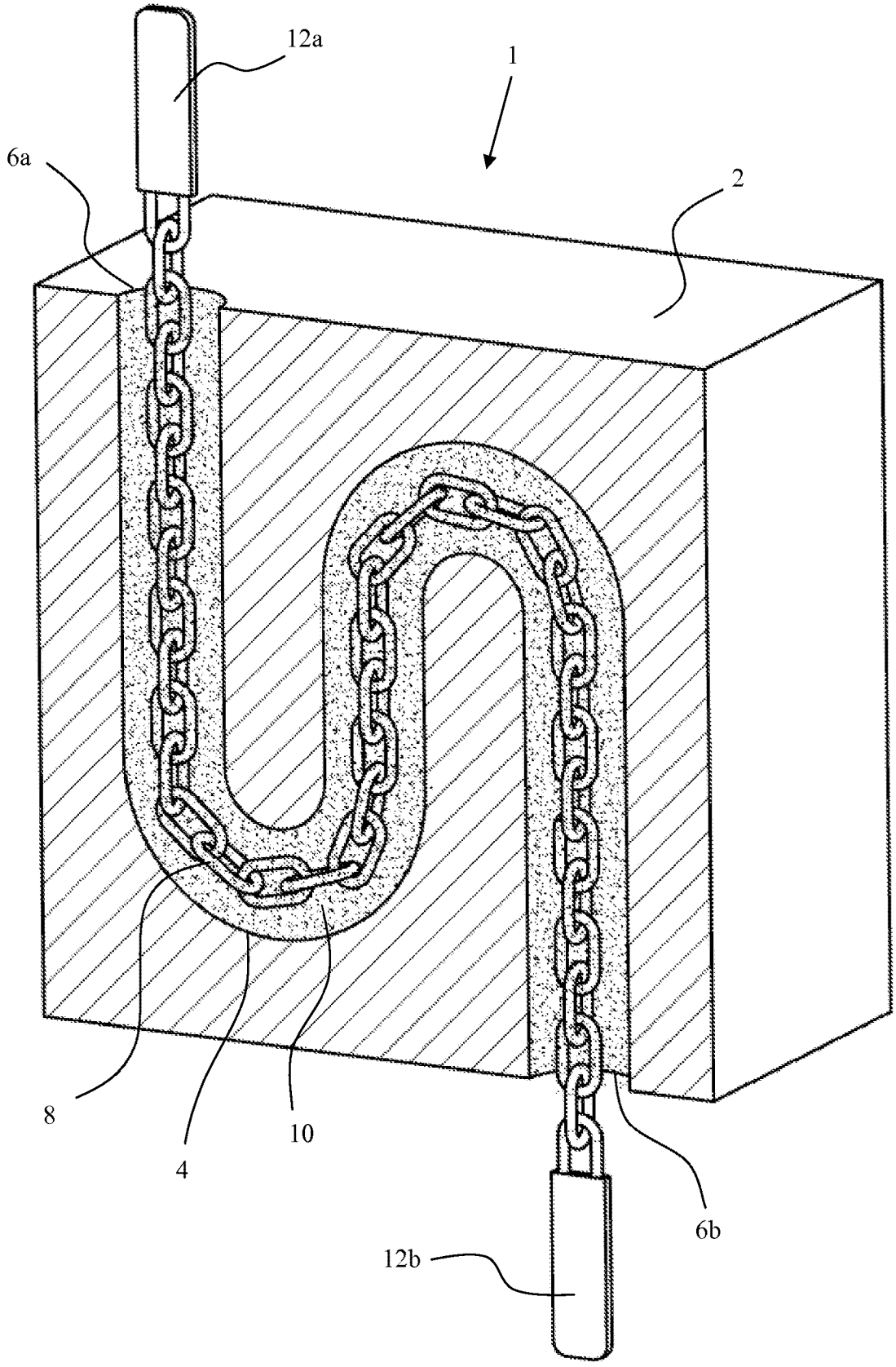

Figure 1

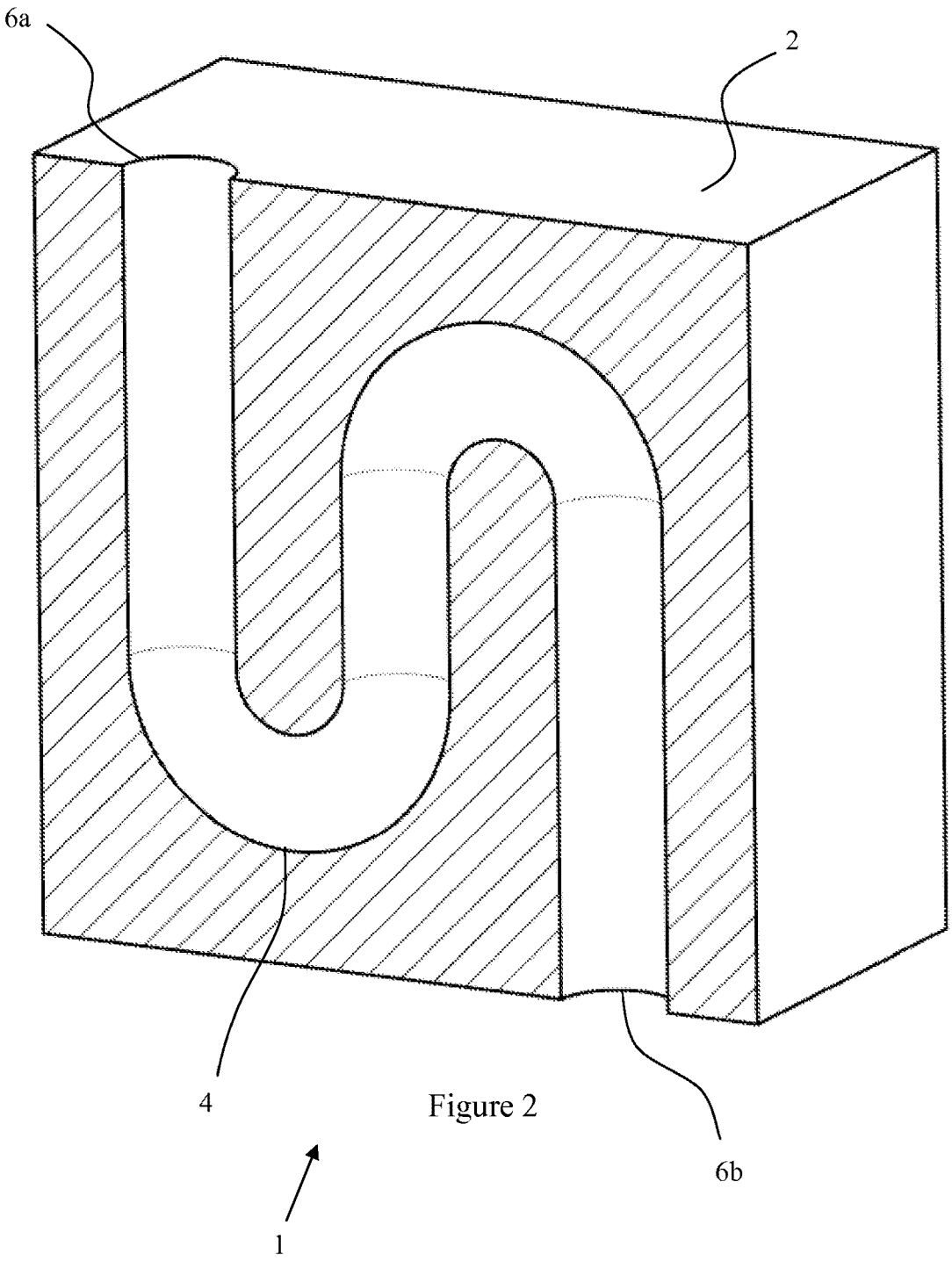

Figure 2

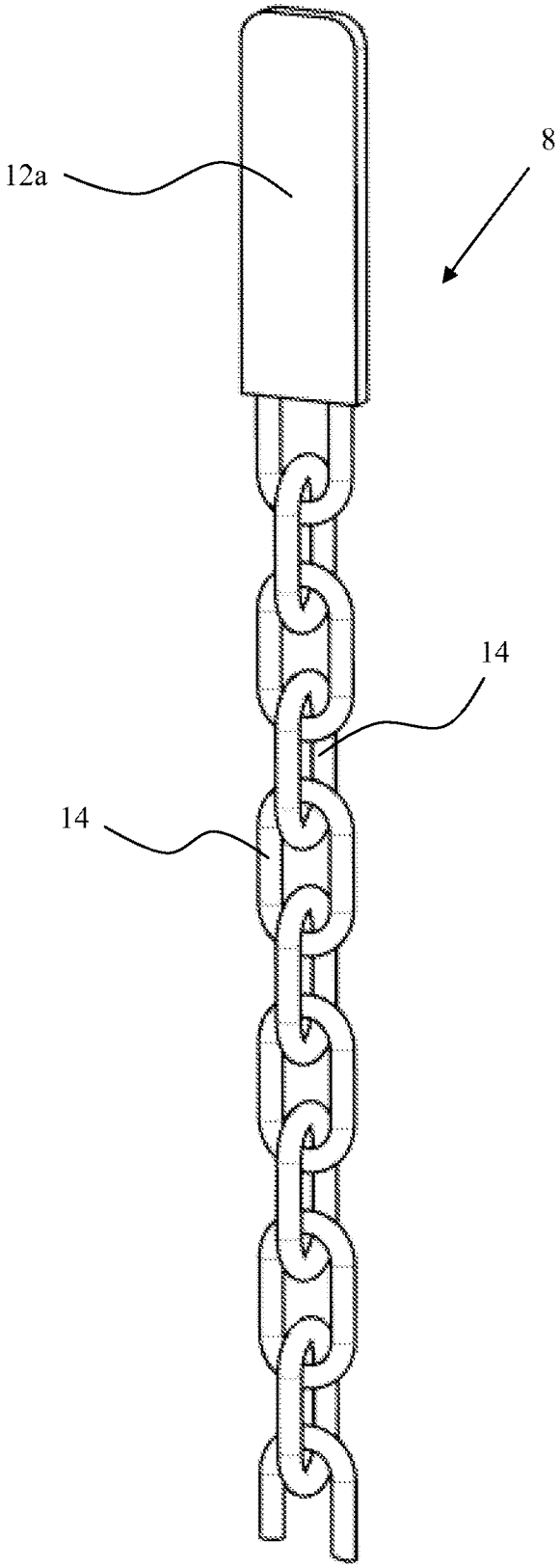

Figure 3

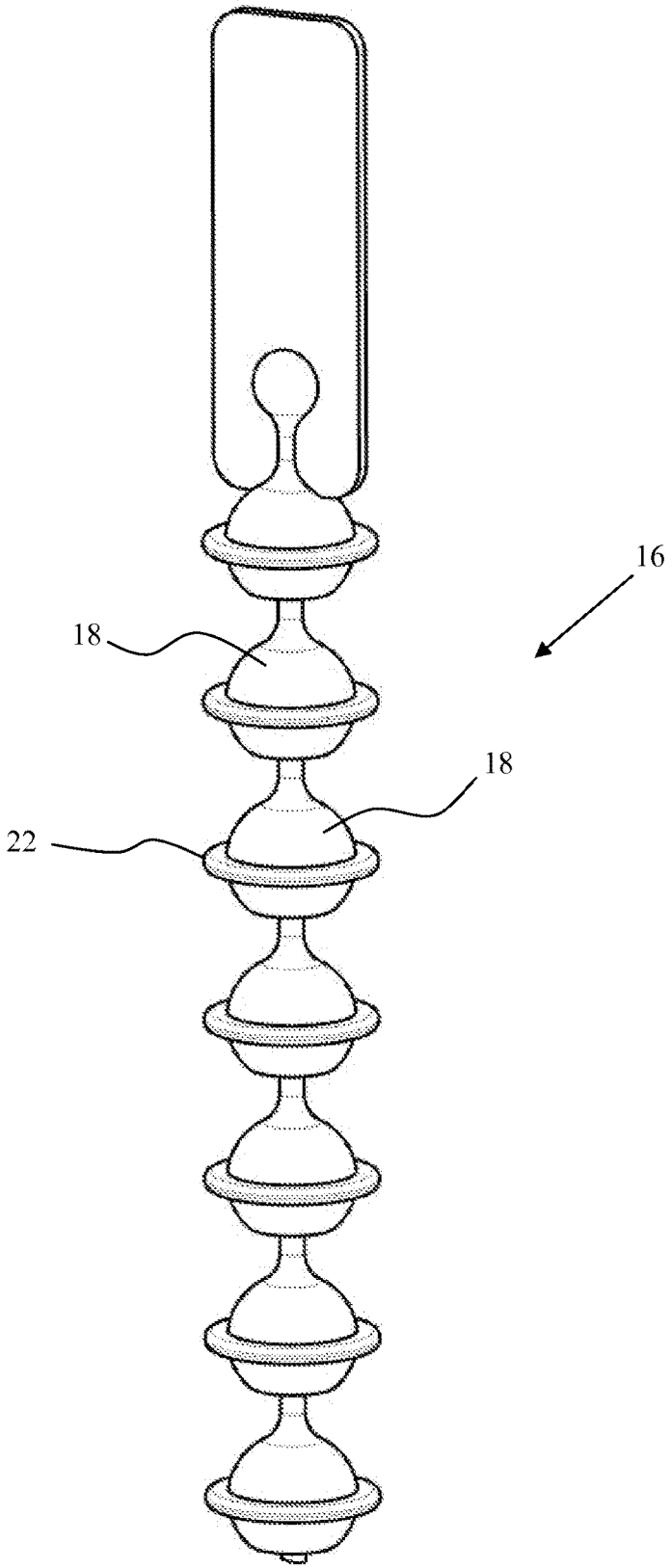

Figure 4

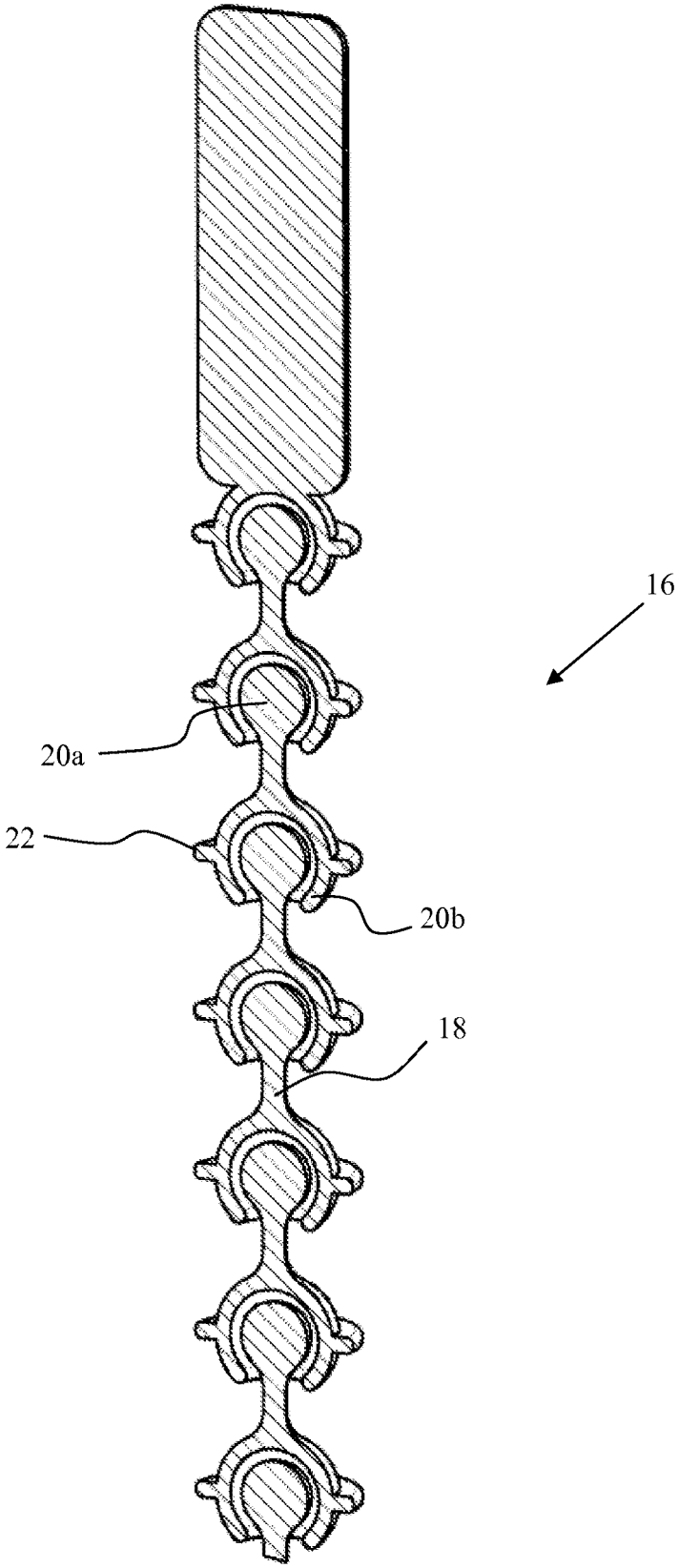

Figure 5

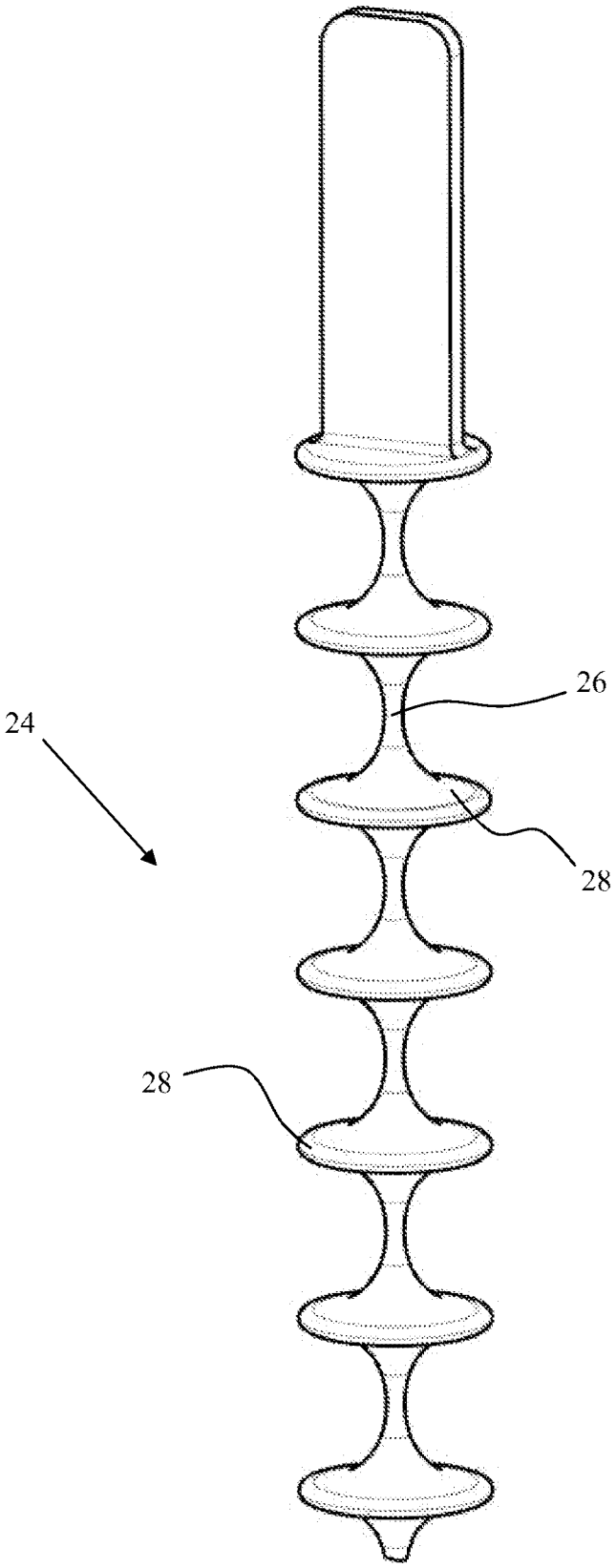

Figure 6

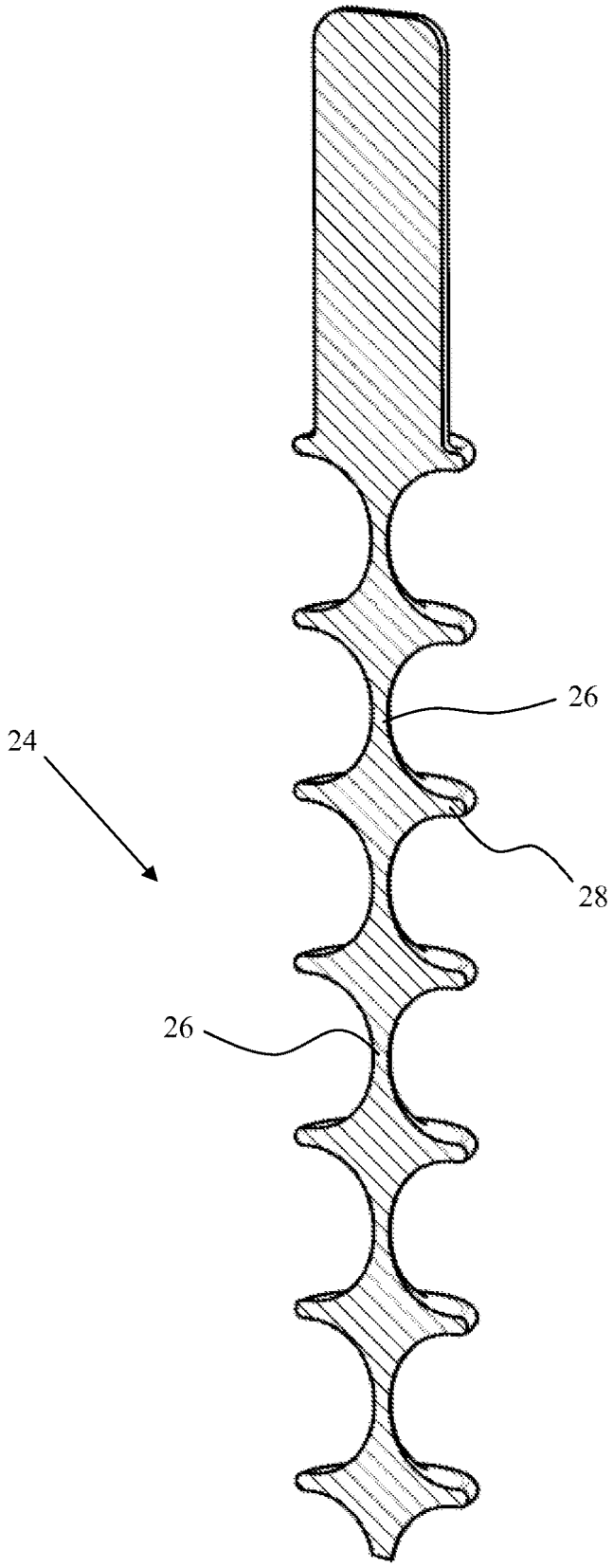

Figure 7

TITLE

Additive manufacturing methods

DESCRIPTION

Field of Invention

The present invention relates to additive manufacturing methods (sometimes called rapid prototyping or 3D printing) where a three-dimensional solid object represented by a digital model such as computer aided design (CAD) data in an appropriate file format is built up from a plurality of cross sections or layers using suitable equipment.

Background Art

Many different types of additive manufacturing methods are known. Some additive manufacturing methods can be described as being self-supporting (i.e., they do not require the creation of additional support structure) so intricate structures and complex features like passageways, channels, conduits and ducts (hereinafter referred to collectively as 'passageways') can be incorporated in the solid object without the need for support. An example of a self-supporting method is selective laser sintering (SLS) where a laser is used to fuse or sinter a powdered material to form the desired object. SLS does not require any additional support structure because the surrounding unsintered powdered material on the build bed acts as a support.

In a typical SLS process, the powdered material is heated to just below its melting point. Powdered material is spread over the build bed by a spreading apparatus and the laser tracks a layer to fuse the powdered material together to form a cross section of the object at that point. After a cross section has been tracked and fused, the build bed is lowered by a layer, a new layer of powdered material is spread on top, and the next cross section is also tracked and fused by the laser. The process is repeated until the object is completed. Once the object has been formed, it is removed from the build chamber and any excess powdered material is removed. A wide range of single- and two-component powdered materials can be used, including plastics, metals, ceramic or glass materials. Specific examples of suitable powdered materials include polymers (e.g., polyamide (nylon), polystyrene, polycarbonate), titanium, steel and

metal alloys, ceramics and ceramic composites, various minerals and mineral composites.

One of the advantages of the SLS process is that it allows objects to have geometries that would be impossible to form using more conventional manufacturing techniques such as machining. However, practical difficulties can arise when a passageway in the finished object needs to be cleared of the unsintered powdered material, particularly if the passageway is convoluted or tortuous. In some cases, the passageway cannot be cleared using normal techniques such as blowing pressurised fluid through it, for example.

Accordingly, there is a need for an improved additive manufacturing method, and in particular a self-supporting method, where powdered material can be removed more easily from a passageway formed in the object.

Summary of the Invention

The present invention provides an additive manufacturing method forming a solid object from powdered material, the solid object having a passageway formed therein with an opening terminating at an outer surface of the solid object, the method comprising the step of forming, at the same time as the remainder of the solid object, a removable component that extends within at least part of the passageway (and preferably along substantially all of the passageway) and is adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

The present invention further provides a method comprising the steps of:

forming a solid object from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein with an opening terminating at an outer surface of the solid object, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least

part of the passageway (and preferably along substantially all of the passageway), and

removing the removable component from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

The present invention further provides a solid object formed from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein with an opening terminating at an outer surface of the solid object, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least part of the passageway (and preferably along substantially all of the passageway) and being adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

Preferably substantially all of the unprocessed powdered material will be cleared from the passageway when the removable component is removed, with any residual powdered material being removed by passing fluid (e.g., a liquid or gas) through the passageway, for example. The fluid can be a pressurised fluid. Although the fluid will typically be introduced after the removable component has been removed from the passageway, it can, additionally or alternatively, be introduced during the removal process, i.e., at the same time as the removable component is being removed.

In some arrangements, the passageway can be fully internal to the solid object as formed by the additive manufacturing process, e.g., it does not have to have an opening terminating at an outer surface of the solid object. In this case, it will typically be necessary to create a further opening to communicate with the passageway (e.g., by drilling or removing part of the solid object) before the removable component can be removed from the passageway.

The object can be formed using any suitable additive manufacturing method. It is generally preferred that a self-supporting additive manufacturing method is used, i.e.,

a method that does not require the creation of additional support structure within the finished object. In a self-supporting additive manufacturing method the layers are supported during the manufacturing process by unprocessed powdered material.

Examples of self-supporting additive manufacturing methods include selective laser sintering (SLS), direct metal laser sintering and melting, and powder-based 3D printing.

All of these additive manufacturing methods are well known to the skilled person and need not be further described. However, additional background information can be obtained from 'Additive Manufacturing Technologies Rapid Prototyping to Direct Digital Manufacturing' by Ian Gibson et al. (ISBN 978-1-4419-1120-9).

Any suitable powdered material can be used.

The object can be formed from one type of powdered material or from two or more types of different powdered material.

It will be readily appreciated that the removable component is provided solely for the purposes of cleaning unprocessed powdered material from the passageway and is not intended to be an integral part of the object as used. As used herein, the term 'intermediate object' refers to the object that is produced using the additive manufacturing method and which includes the removable component *in situ*, and the term 'final object' refers to the object in the form in which it is intended to be used after the removable component has been removed from the passageway. The removable component is included as part of the digital model of the object that is used by the additive manufacturing method to create the intermediate object and is formed as part of the intermediate object in a single manufacturing step. Once the removable component has been removed from the passageway it typically has no further use and can be discarded.

The passageway can have a practical or technical function. For example, if the final object is a fluid manifold then the passageway can be a flow channel for a gas or liquid. If the final object is a loudspeaker enclosure (or box) then the passageway can be a sound channel that is designed to create resonant back-pressure at certain frequencies to tune the enclosure to a particular frequency range. However, the passageway does not need to have a practical or technical function and can be provided in the final object for purely aesthetic reasons.

The passageway can be convoluted or tortuous. In other words, the passageway can follow a twisted pathway through the body of the object.

The removable component can have any suitable construction, but it is generally preferred that it is articulated (i.e., formed as two or more sections that are connected together to allow flexibility of movement or by a flexible joint). An articulated removable component can be easily removed from a convoluted or tortuous passageway and can also be 'pumped' (i.e., rapidly moved backwards and forwards) to release it from, and to help with the removal of, compacted powdered material. The removable component can also be twisted, or rotated, or moved from side to side within the passageway for the same reasons.

In one arrangement the articulated removable component includes a plurality of chain links or inter-connected sections, each chain link or section being formed by the additive manufacturing method. The individual chain links or sections are typically formed within the passageway in a linked or inter-connected arrangement and can either be separately formed or physically connected together by frangible connections or bridges that break when the removable component is first manipulated by a user to allow the chain links or sections flexibility of movement. In another arrangement the articulated removable component is formed as a single component with a plurality of regions of flexure or in the form of a mesh of interlocking links or fibres that might be adapted to 'scour' the passageway on removal. Such 'scouring' might also be achieved by twisting or rotating the removable component as it is being removed. It will be readily understood that other specific types and construction of removable

component can be formed within the passageway of the intermediate object during the additive manufacturing method provided that they are capable of being physically removed from the passageway and that any unprocessed powdered material remaining within the passageway is at least partly removed by the removable component as it is withdrawn by the user.

The removable component can be shaped and/or include surface features designed to assist with clearing the unprocessed powdered material from the passageway when the removable component is removed.

The removable component can be aligned substantially along a centreline of the passageway.

The removable component can be spaced apart from the walls defining the passageway within the intermediate object, i.e., the removable component is surrounded by a layer of unprocessed powdered material, so that it is not physically connected to the remainder of the intermediate object. The removable component can also be physically connected to the remainder of the intermediate object by one or more frangible connections or bridges that break when the removable component is first manipulated by a user to allow the removable component to be removed from the passageway.

The removable component can include a part that extends beyond the opening at the outer surface of the object and which is adapted to be grasped by a user preparatory to removing the removable component from the passageway.

Two or more removable components can be formed within a single passageway.

Drawings

Figure 1 is a cross section through part of a manifold according to the present invention with a removable component *in situ* within a passageway;

Figure 2 is a cross section through the manifold of Figure 1 where the removable component has been removed from the passageway;

Figure 3 is a detail view showing a removable component having a first construction;

Figures 4 and 5 are detail views showing a removable component having a second construction; and

Figures 6 and 7 are detail views showing a removable component having a third construction.

Figure 1 shows part of a fluid manifold 1 made of sintered polyamide (nylon) powder and which has been formed by a selective laser sintering (SLS) process.

The manifold body 2 includes a convoluted or tortuous fluid flow channel 4. In practice, the manifold body 2 will include a plurality of channels, each terminating at an opening or port provided at the outer surface of the manifold body. The channel 4 shown in Figure 1 has a first opening 6a and a second opening 6b.

An articulated removable component 8 is located in the channel 4 and is formed by the SLS process at the same time as the manifold body 2.

The removable component 8 extends along a centreline of the channel 4 and is spaced apart from the manifold body 2 by unsintered polyamide powder 10. A first end 12a of the removable component 8 extends beyond the first opening 6a where it can be grasped by a user preparatory to removing it from the channel 4. A second end 12b of the removable component 8 extends beyond the second opening 6b. The first and second ends 12a, 12b are configured as pull tabs but in practice they can have any suitable shape or configuration that can be easily grasped by a user. As the removable component 8 is withdrawn from the channel 4, it removes the majority of the surrounding polyamide powder 10 with it. The removable component 8 can be discarded once it has been removed from the channel 4 because it is not an integral part of the final fluid manifold. Any residual polyamide powder can be removed by passing pressurised air through the channel 4.

Figure 2 shows the manifold body 2 in its final form once the removable component 8 and unsintered polyamide powder 10 have been removed from the passageway 4.

The removable component can have any suitable construction. In one arrangement shown in Figures 1 and 3 the removable component 8 is in the form of a chain and consists of a plurality of chain links 14.

In another arrangement shown in Figures 4 and 5 the removable component 16 consists of a plurality of inter-connected sections 18. Each section 18 has a ball end 20a and a cup end 20b, the cup end being shaped and sized to receive and retain the ball end of an adjacent section. The cup end 20b is also formed with an annular flange 22 that can assist with the removal of the unsintered polyamide powder from the passageway 4.

The individual chain links 14 and sections 18 are formed during the SLS process.

In yet another arrangement shown in Figures 6 and 7 the removable component 24 consists of an integral, component with a plurality of 'necks' or regions of flexure 26. In other words, the removable component 24 consists of a plurality of sections 28 inter-connected by the regions of flexure 26. The sections 28 have a disc-like construction that can assist with the removal of the unsintered polyamide powder from the passageway 4.

All of these removable components are articulated (i.e., formed as two or more sections that are connected together to allow flexibility of movement or by a flexible joint). Such articulation or flexibility of movement allows the removable component that is formed during the SLS process to be aligned along the centreline of a convoluted or tortuous channel and also allows the removable component to be withdrawn from such a channel because it can flex around the bends.

The removable component can be 'pumped' (i.e., rapidly moved backwards and forwards), and/or twisted by the user to release it from the surrounding polyamide powder. This also helps with the removable of any compacted polyamide powder.

Other types of self-supporting additive manufacturing methods, articulated removable components, powder etc. can be used. Although the present invention has been described with reference to a fluid manifold, it will be readily appreciated that other types of object can also be formed with a removable component in a similar manner.

CLAIMS

1. An additive manufacturing method forming a solid object from powdered material, the solid object having a passageway formed therein with an opening terminating at an outer surface of the solid object, the method comprising the step of forming, at the same time as the remainder of the solid object, a removable component that extends within at least part of the passageway and is adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

2. A method comprising the steps of:

forming a solid object from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein with an opening terminating at an outer surface of the solid object, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least part of the passageway, and

removing the removable component from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

3. A method according to claim 1 or claim 2, wherein the powdered material is a polymer or metal.

4. A method according to any preceding claim, wherein the removable component is articulated.

5. A method according to any preceding claim, wherein the removable component includes part that extends beyond the opening and which is adapted to be grasped by a user preparatory to removing the removable component from the passageway.

6. A method according to any preceding claim, wherein the passageway formed in the solid object is convoluted or tortuous.

7. A method according to claim 2, further comprising the step of passing fluid through the passageway after the removable component has been removed, or while the removable component is being removed.

8. A method according to claim 7, wherein the fluid is a pressurised fluid.

9. A method according to any preceding claim, wherein the additive manufacturing method is a self-supporting additive manufacturing method.

10. A solid object formed from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein with an opening terminating at an outer surface of the solid object, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least part of the passageway and being adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

11. A solid object according to claim 10, being formed from a powdered polymer or metal.

12. A solid object according to claim 10 or claim 11, wherein the removable component is articulated.

13. A solid object according to any of claims 10 to 12, wherein the removable component includes part that extends beyond the opening and which is adapted to be grasped by a user preparatory to removing the removable component from the passageway.

14. A solid object according to any of claims 10 to 13, wherein the passageway formed in the solid object is convoluted or tortuous.

15. A solid object substantially as described herein and with reference to the drawings.

AMENDMENTS TO THE CLAIMS HAVE BEEN FILED AS FOLLOWS:

CLAIMS

1. An additive manufacturing method forming a solid object from powdered material, the solid object having a passageway formed therein, the method comprising the step of forming, at the same time as the remainder of the solid object, a removable component that extends within at least part of the passageway and is adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

2. A method comprising the steps of:

forming a solid object from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least part of the passageway, and

removing the removable component from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

3. A method according to claim 1 or claim 2, wherein the passageway has an opening terminating at an outer surface of the solid object.

4. A method according to claim 3, wherein the removable component includes part that extends beyond the opening and which is adapted to be grasped by a user preparatory to removing the removable component from the passageway.

5. A method according to claim 1, wherein the passageway is fully internal to the solid object.

6. A method according to claim 2, wherein the passageway is fully internal to the solid object and the method further comprises the step of creating an opening to communicate with the passageway before removing the removable component from the passageway.

7. A method according to claim 6, wherein the step of creating the opening includes drilling or removing part of the solid object.

8. A method according to any preceding claim, wherein the powdered material is a polymer or metal.

9. A method according to any preceding claim, wherein the removable component is articulated.

10. A method according to any preceding claim, wherein the passageway formed in the solid object is convoluted or tortuous.

11. A method according to claim 2, further comprising the step of passing fluid through the passageway after the removable component has been removed, or while the removable component is being removed.

12. A method according to claim 11, wherein the fluid is a pressurised fluid.

13. A method according to any preceding claim, wherein the additive manufacturing method is a self-supporting additive manufacturing method.

14. A solid object formed from powdered material using an additive manufacturing method, the solid object including:

a passageway formed therein, and

a removable component formed at the same time as the remainder of the solid object, the removable component extending within at least part of the passageway and being adapted to be subsequently removed from the passageway thereby to at least partially clear the passageway of unprocessed powdered material.

15. A solid object according to claim 14, wherein the passageway has an opening terminating at an outer surface of the solid object.

16. A solid object according to claim 15, wherein the removable component includes part that extends beyond the opening and which is adapted to be grasped by a user preparatory to removing the removable component from the passageway.

17. A solid object according to claim 14, wherein the wherein the passageway is fully internal to the solid object.

18. A solid object according to any of claims 14 to 17, being formed from a powdered polymer or metal.

19. A solid object according to any of claims 14 to 18, wherein the removable component is articulated.

20. A solid object according to any of claims 14 to 19, wherein the passageway formed in the solid object is convoluted or tortuous.

21. A solid object substantially as described herein and with reference to the drawings.

Application No: GB1315083.4 **Examiner:** Mr Philip Osman

Claims searched: 1-15 **Date of search:** 20 February 2014

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
		None

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B22F; B29C

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B29C	0067/00	01/01/2006
B22F	0003/105	01/01/2006